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## THE MORPHOLOGY-DENSITY RELATION FOR DWARF GALAXIES

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## ABSTRACT

The morphology-density relation is examined for dwarf galaxies with absolute magnitudes  $-18 \leq M_{BT} \leq -12.5$ , based on a deep photographic survey of nearby groups and clusters of galaxies. The following results are presented: (1) Compared to dwarf ellipticals, dwarf irregulars form a more extended population in nearby clusters, and may in fact be entirely absent from the cluster cores. (2) The spatial distribution of dwarf ellipticals in clusters depends on luminosity and the presence or absence of nucleation. Nucleated dE's and non-nucleated dE's fainter than  $M_{BT} \sim -13.5$  are concentrated toward the centers of clusters like the giant E and S0 galaxies. In contrast, non-nucleated dE's brighter than  $M_{BT} \sim -14.5$  are distributed like the spirals and irregulars. (3) The intrinsic shapes of the bright non-nucleated dE's are similar to those of the dwarf irregulars, suggesting a possible evolutionary connection between these two classes of galaxies.

## INTRODUCTION

It is well known that elliptical and S0 galaxies dominate the central high-density regions of galaxy clusters, while spirals are preferentially found in low-density regions (Hubble and Humason 1931; Dressler 1980). Theoretical mechanisms that have been proposed to explain this include tidal stripping of gas from galaxies during close encounters and mergers, ram pressure sweeping of HI due to galaxy motion through the intra-cluster medium, gas evaporation, and conditions at the time of galaxy formation. Because these processes depend in different ways on galaxy mass and cluster properties, observations of dwarf galaxies in a range of environments offer us the opportunity to test which processes are most important.

As an extension of the Virgo Cluster Survey (Binggeli, Sandage and Tammann 1985; hereafter BST85), six additional groups of galaxies have been surveyed from Las Campanas Observatory using the 2.5 m du Pont telescope, nearly doubling the sample of galaxies and probing a different set of environmental conditions.

## THE MORPHOLOGY-DENSITY RELATION

Fig 1. shows the morphology-density relation down to different limiting magnitudes for our entire sample. Nucleated dE's are the most strongly clustered toward dense environments, while irregulars are the least. Dwarf ellipticals without nuclei are, in general, less concentrated toward dense environments than nucleated dE's, but the degree of concentration depends on the luminosity cutoff. To examine the different spatial distributions in more detail, in Figs. 2 and 3 we plot the projected densities of various types of galaxies as a function of radius in the Fornax and Virgo Clusters. Exponentials have been fit to the radial profiles with results shown in Table 1. The radial profiles of the E+S0's, nucleated dE's and faint non-nucleated dE's are all the same to within the uncertainties. Similarly, the radial profiles of the spirals, irregulars, and bright non-nucleated dE's are indistinguishable.

## THE dE-Im CONNECTION

There are several possible explanations for the more extended radial distribution of the bright non-nucleated dE's. First, the sample could be contaminated by foreground galaxies, a possibility that appears unlikely based on the luminosity function of dwarfs in groups of varying distances in our survey. Second, the bright non-nucleated dE's could be the dormant phase of dwarf irregular galaxies between bursts of star formation, as predicted in "Stochastic Self Propagating Star Formation" (SSPSF) models (Gerola, Seiden, and Shulman 1980; Tyson and Scalo 1988). Third, they could be the stripped remnants of dwarf irregulars that have passed through the cluster cores on radial orbits. The last two possibilities suggest that bright dE's should be flattened systems, like the dwarf

Table 1. Type-dependent density profiles in the Virgo and Fornax Clusters

Exponential profiles for Virgo							
Sample	$M_{B_T}$ range	N	Best fit $1/\alpha$ (deg.)	70% confidence min. max.	99% confidence min. max.		
E+S0		62	1.61*	1.4* 2.0*	1.1* 2.8*		
Sa+Sb+Sc		78	3.08	2.4 4.2	1.9 9.1		
Sd-Im	$\leq -14.2$	74	3.77	2.9 5.6	2.1 22.2		
faint dE(no N)	$> -13.3$	256	1.72	1.6 1.9	1.4 2.2		
bright dE(no N)	$\leq -14.2$	112	3.90	3.1 5.6	2.3 12.5		
dE,N	$\leq -14.2$	151	1.61	1.5 1.8	1.3 2.2		

Exponential profiles for Fornax							
Sample	$M_{B_T}$ range	N	Best fit $1/\alpha$ (deg.)	70% confidence min. max.	99% confidence min. max.		
E+S0		31	0.87	0.7 1.1	0.6 1.4		
Sa+Sb+Sc		18	2.46	1.6 5.3	1.0 >50.0		
Sd-Im	$\leq -14.2$	27	4.08	2.4 14.3	1.5 >50.0		
faint dE(no N)	$> -13.3$	66	0.67	0.6 0.7	0.5 0.9		
bright dE(no N)	$\leq -14.2$	34	2.69	1.9 4.6	1.3 >50.0		
dE,N	$\leq -14.2$	57	0.87	.8 1.0	.6 1.3		

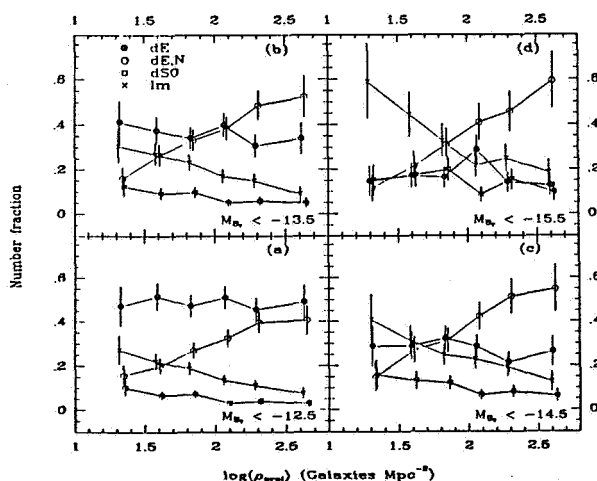


Fig. 1 - Morphology-density relation for dwarf galaxies. Late-type galaxies (Sd, Sdm, Sm and Im galaxies) are shown as crosses, dS0's as open squares, non-nucleated dE's as filled circles, and nucleated dE's as open circles. Projected densities are computed by counting the ten nearest neighbors brighter than  $M_{B_T} = -12.5$ .

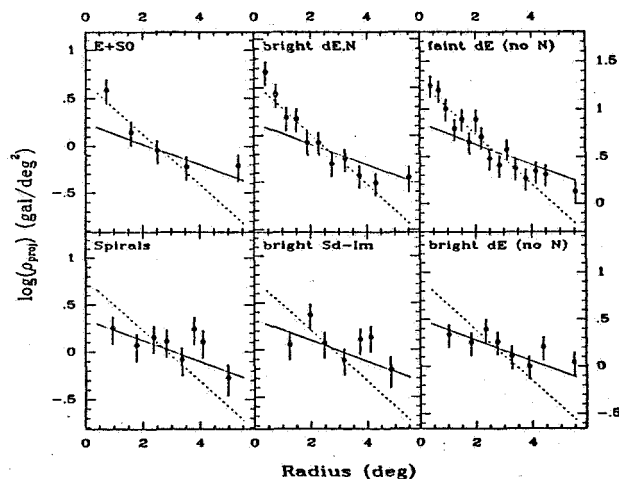


Fig. 2 - The projected density of galaxies as a function of radius in the Virgo Cluster. The solid line shows the best-fit exponential to the bright non-nucleated dE distribution; the dotted line shows the best fit to the faint non-nucleated dE distribution. Both fits are normalized to the number of galaxies in each sample. The fits were performed on the unbinned distributions using a maximum likelihood technique. Galaxies south of  $9^\circ$  declination and in the M and W clouds have been excluded. The bright samples contain galaxies down to  $M_{B_T} = -14.2$  ( $B_T = 17.5$ ). The faint dE sample contains galaxies fainter than  $M_{B_T} = -13.1$ .

irregulars. In Fig. 4., we compare the flattening distributions of the nucleated and non-nucleated dwarf ellipticals and the dwarf irregulars in the same luminosity range. The similarity of the distributions for the non-nucleated dE's and the irregulars supports the picture that the two classes are related.

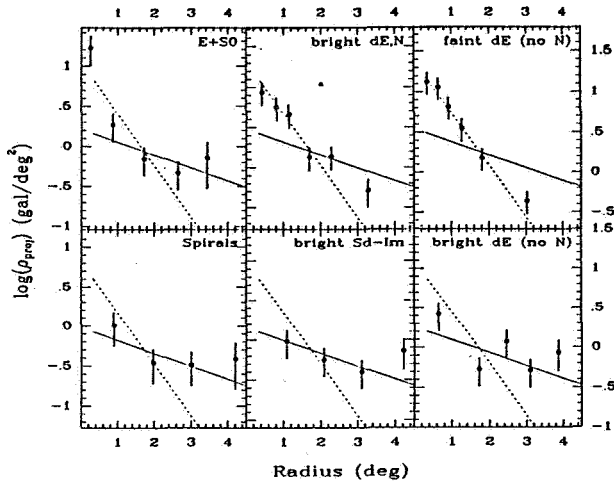


Fig. 3 – The projected density of galaxies as a function of radius in the Fornax Cluster. The solid line shows the best-fit exponential to the bright non-nucleated dE distribution; the dotted line shows the best fit to the faint non-nucleated dE distribution.

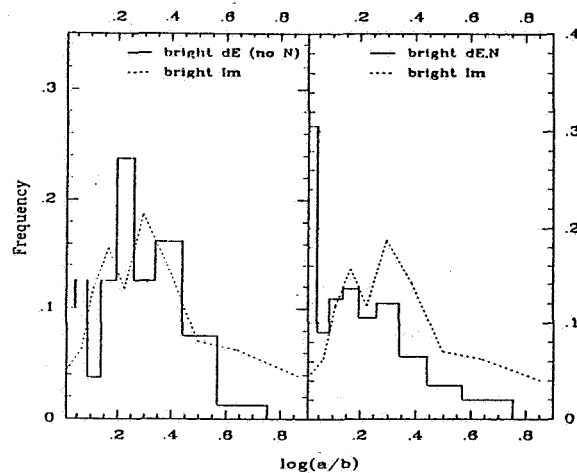


Fig. 4 – The distribution of axial ratios for bright nucleated and non-nucleated dE galaxies, and dwarf irregulars. The samples include galaxies brighter than  $M_{B_T} = -14.7$  from the Leo, Dorado, and NGC1400 groups and the Fornax and Virgo Clusters. The Im sample includes 129 Sd, Sdm, Sm, and Im galaxies. The dE,N sample includes 200 galaxies, and the non-nucleated dE sample includes 83 galaxies. The bins in axial ratio are those used by Sandage, Freeman, and Stokes (1970).

### TESTS OF THE EVOLUTIONARY STATE OF dE's

HI observations of a sample of bright non-nucleated dE's are necessary to test the SSPSF models. Dwarf irregulars between bursts of star formation should be rich in HI. Only about 5 non-nucleated dE's brighter than  $M_{B_T} = -14.5$  have been observed to date with Arecibo (Bothun *et al.* 1986; Impey *et al.* 1988). None have been detected. Nonetheless, it would be useful to have a larger sample to make the test more conclusive.

Finally, we propose two tests of the hypothesis that the bright non-nucleated dE's are stripped irregulars. First, the similarity of the spatial distributions can be understood if the dwarf irregulars are on predominantly radial orbits. The dwarf irregulars have a higher velocity dispersion than the early-type cluster members (Hoffman *et al.* 1987), consistent with this picture, but the orbit distribution has not yet been examined in detail. Second, if the non-nucleated dE's are stripped Im's, then their metal abundances should be similar. The dE's as a whole are more metal rich than irregulars, but the comparison must now be carried out separately for the nucleated and non-nucleated dE's.

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